ISBN: 978-628-96613-3-0. ISSN: 2414-6390. Digital Object Identifier: https://dx.doi.org/10.18687/LACCEI2026.1.1.678

Design and Evaluation of an AI-Supported Global Shared Learning Strategy in Engineering Science Courses

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Abstract*– This paper analyses a Global Shared Learning Classroom (GSL) experience developed between undergraduate students from the Dominican Republic and Puebla, Mexico, focused on collaborative research into the relevance of different vitamins for human health. The study was implemented as a pilot quasi-experimental design, integrating international collaborative learning, digital tools, and regulated artificial intelligence support as part of a structured pedagogical architecture. The intervention was articulated through the Dynamic Table for Research and Dissemination (TABDIM), used to organize, systematize, and synthesize the scientific information generated by binational teams. Students analyzed various vitamins considering physicochemical properties, biochemical functions, health implications, food sources, and practical applications. To support the research process, the specialized chatbot Albiomim was integrated as a cognitive scaffolding tool for consultation and conceptual clarification. The outcomes of the collaborative work were presented through a dynamic digital poster within an immersive virtual environment accessible via avatars, complemented by a reflective phase supported by the Padlet platform. Quantitative analysis of the results revealed a significant increase in conceptual learning, with mean scores rising from 65.68 to 78.18, along with a strong positive correlation between pre- and post-intervention results (r = 0.8006). Overall, the findings suggest that the intentional and structured integration of international collaboration, experiential learning, digital tools, and artificial intelligence contributes positively to conceptual learning, student engagement, and the overall learning experience in science courses for engineering education, providing relevant evidence for the design of innovative learning environments in higher education.

Keywords*-- Engineering education, experiential learning, educational innovation, artificial intelligence, global share learning classroom.

I. Introduction

The transformation of higher education in Latin America and comparable global contexts has become a structural challenge that requires the coherent articulation of international collaboration, innovative pedagogical models, and the strategic use of digital technologies and artificial intelligence, oriented toward competency development and educational sustainability [1-3]. Recent literature consistently indicates that traditional instructional environments are insufficient to address the cognitive, social, and professional demands of the twenty-first century, particularly in scientific and engineering disciplines that require conceptual integration, systemic thinking, and evidence-based decision making [4-5].

Within this context, the Global Shared Learning Classroom (GSLC) model has consolidated as a high-impact pedagogical strategy by promoting structured international collaborative learning experiences capable of strengthening transversal competencies such as intercultural communication, teamwork, critical thinking, and social responsibility. Recent empirical evidence shows that when global collaboration is intentionally integrated into the curriculum, significant improvements are observed in student engagement, knowledge transfer, and the development of competencies aligned with the Sustainable Development Goals [6-8].

Complementarily, recent studies have emphasized that the integration of digital technologies and artificial intelligence into educational environments not only fosters pedagogical innovation but also introduces significant challenges related to faculty preparedness, institutional infrastructure, and the persistence of digital divides. These factors are critical for ensuring equity and long-term sustainability in higher education. From this perspective, the use of technology must move beyond an instrumental rationale and be conceived as part of a coherent pedagogical architecture capable of articulating active learning, authentic assessment, and international collaboration [9,10].

Previous research has demonstrated that experiential learning supported by emerging technologies, including virtual environments, virtual reality, and language-model-based conversational agents, contributes significantly to the development of complex competencies and interdisciplinary problem solving. Virtual reality has been shown to function as a flexible pedagogical resource capable of enhancing engineering education through immersive and context-rich learning experiences [3]. Subsequent studies have reported that the integration of experiential and collaborative learning approaches facilitates effective knowledge transfer across disciplines and professional contexts [11]. More recently, the regulated integration of GPT-based language models, combined with experiential learning and reinforcement strategies, has been shown to positively impact complex problem solving and students' analytical reasoning [12].

From a disciplinary standpoint, the teaching of content related to biology, biochemistry, and nutrition represents a particularly relevant opportunity for implementing experiential and interdisciplinary educational approaches, given their direct impact on human health and their inherently integrative nature. Applied research has emphasized the importance of embedding contextualized scientific knowledge into educational processes, fostering evidence-based training that supports informed decision making in health and nutrition contexts [13]. Within this framework, the study of vitamins enables the articulation of physicochemical, biochemical, and structural concepts with practical and socially relevant applications.

Moreover, recent literature highlights the emerging role of artificial intelligence and educational chatbots as tools that facilitate learning personalization, immediate feedback, and cognitive support during research processes, provided that their implementation is guided by pedagogical, ethical, and sustainability criteria [14]. When integrated as cognitive scaffolding mechanisms, these systems can enhance student autonomy and improve the quality of academic output without replacing critical judgment or the formative role of the instructor.

In this context, the present article analyzes a Global Shared Learning Classroom project developed between students from Pontificia Universidad Católica Madre y Maestra (PUCMM), Dominican Republic, and Tecnológico de Monterrey (ITESM), Puebla, Mexico, focused on collaborative research on vitamins and their relevance to human health. The project was supported by a pedagogical architecture integrating collaborative digital tools, an online Dynamic Table for Research and Dissemination (TABDIM), and the use of the specialized chatbot Albiomim, oriented toward food science, biology, and biochemistry content. The outcomes of the collaborative work materialized through an interactive digital poster presented in an immersive virtual environment accessible via avatars, followed by a collective reflection process supported by the Padlet platform.

From a research perspective, this study aims to analyze the impact of this AI-supported GSL strategy in terms of conceptual learning, student engagement, and perceived usefulness, contributing to the discussion on the design of hybrid and international educational environments in higher education. In doing so, the work seeks to provide empirical evidence on how the intentional integration of global collaboration, experiential learning, and artificial intelligence tools can enrich the teaching of complex scientific content in university contexts.

In this study, the independent pedagogical construct under analysis is not technology use per se, but the intentional orchestration of global collaboration, structured cognitive scaffolding, and regulated AI support within a unified instructional architecture.

II. Helpful Hints

A. Methodological Approach and Study Design.

This study was conducted under a pilot quasi-experimental design with a mixed (quantitative-descriptive) approach, aimed at analyzing the impact of a Global Shared Learning Classroom (GSL) strategy supported by collaborative digital tools and artificial intelligence on conceptual learning, student engagement, and perceived usefulness among undergraduate engineering students.

This approach is justified by the fact that the study was implemented in an authentic educational context, without random assignment of participants to control and experimental groups, thereby prioritizing the ecological validity of the intervention. Consequently, the results are interpreted as exploratory evidence, allowing for the identification of trends, associations, and preliminary effects derived from the implemented pedagogical strategy.

B. *Educational Context and Participants*

The intervention was carried out within the framework of a Global Shared Learning Classroom experience, jointly developed between Pontificia Universidad Católica Madre y Maestra (PUCMM), Dominican Republic, and Tecnológico de Monterrey (ITESM), Puebla campus, Mexico. The sample consisted of n = 22 students enrolled in the course IB1005 Fundamentals of Biological Systems, belonging to engineering programs.

Students participated voluntarily and completed the experience as part of the regular academic activities of the course. The population exhibited a heterogeneous background in terms of prior knowledge of biology and biochemistry, which allowed for the analysis of the intervention's effects in a context representative of introductory science courses for engineering education.

C. Instructional Design of the GSL Strategy.

The pedagogical strategy was designed based on principles of active learning, experiential learning, and structured international collaboration, integrating guided research activities, multimodal academic production, and metacognitive reflection.

Students were organized into binational teams, including members from both institutions, with the purpose of fostering intercultural interaction, distributed academic communication, and both asynchronous and synchronous collaborative work. Each team selected a specific vitamin as the object of study, approaching it from an interdisciplinary perspective that integrated content from biology, biochemistry, physiochemistry, and applied nutrition.

The research process was articulated through the Dynamic Table for Research and Dissemination (TABDIM), conceived not merely as an information organization tool but as a pedagogical architecture for progressive cognitive scaffolding. The general structure of TABDIM is presented in ANNEXES, while the methodological phases that comprise it are detailed in Table I.

TABLE I. PHASES OF TABDIM METHODOLOGY

Phase	Name	Description
I	TEAMS	Generation of mixed teams between the two countries.
II	TOPIC	Establish the topic to be developed.
III	PHASES 5X5	Establish the phases to be developed, with 5-by-5 data points to be investigated, supported by ALBIOMIM.
IV	SHORT SUMMARY	Establish summaries at the end of each 5 research elements.
V	POSTER	Compilation of summaries in a dynamic poster (with integrated videos).
VI	DEFENSE	Defense of the poster by the team members.

D Methodological Structure of TABDIM.

TABDIM was organized into six sequential phases, designed to guide the processes of research, synthesis, and scientific communication:

1.- Teams: formation of binational teams, promoting academic and cultural diversity.

2.- Topic: consensual definition of the object of study (specific vitamin).

3.- 5×5 Phases: development of research cycles structured into blocks of five guiding questions or key elements, supported by the ALBIOMIM chatbot.

4.- Short Summary: preparation of partial syntheses at the end of each block, fostering conceptual consolidation.

5.- Poster: integration of the summaries into a dynamic digital poster incorporating multimedia resources.

6.- Defense: oral presentation and defense of the poster by the team members.

This design enabled the implementation of an iterative research-synthesis-reflection process, aligned with experiential learning models and principles of authentic assessment.

E. Structure of Disciplinary Analysis.

The investigation of each vitamin was organized into five thematic blocks, which functioned as axes of scientific inquiry:

- Physicochemical properties, addressing solubility, antioxidant function, essential physiological roles, relationships with the immune system, and involvement in cellular differentiation processes.
- Biochemical interactions and functions, analyzing the role as a cofactor, interactions with metals or non-metals, antiviral and immunomodulatory effects, participation in cellular signaling pathways, and associations with specific enzymes, including references to PDB codes when applicable.
- Structural properties, considering molecular weight, acid–base character, thermal stability, types of chemical bonds, atomic composition, and nanometric-scale dimensions.
- Distribution and content in foods, identifying dietary sources, relative concentrations, growth times of vitamin-containing foods, comparisons with other vitamins, and culinary applications.
- Accessibility and regional denominations, analyzing costs, regional naming conventions across cultural contexts, diseases associated with vitamin deficiency, and available pharmaceutical products.

This organization enabled students to develop a systemic, contextualized, and applied understanding of the object of study.

F. Integration of Artificial Intelligence as Cognitive Scaffolding

During the research process, students used the ALBIOMIM chatbot, specializing in food science, biology, and biochemistry content. The chatbot was integrated as a regulated cognitive scaffolding tool, oriented toward:

- Resolving conceptual questions during the research process.
- Guiding the search and organization of scientific information.
- Supporting the development of partial summaries within the 5×5 phases.

It is important to emphasize that the use of ALBIOMIM did not replace students' critical analysis or academic decision making; rather, it functioned as a supporting resource integrated within a clearly defined pedagogical sequence.

G. Final Product and Evaluation Process.

As a final product, each team developed a dynamic digital poster integrating summaries, images, diagrams, audio elements, and explanatory videos, coherently presenting the results of the conducted research. This poster was presented and defended orally, promoting the development of scientific argumentation and academic communication competencies.

To evaluate the impact of the intervention, three complementary instruments were applied:

1.- A knowledge questionnaire, administered before and after the intervention, aimed at analyzing changes in conceptual learning.

2.- A student engagement questionnaire, focused on motivational, participatory, and self-regulation dimensions.

3.- An impact and usefulness questionnaire, designed to assess students' perceptions of TABDIM and the use of the ALBIOMIM chatbot.

The combination of these instruments allowed for the analysis of the strategy's impact from cognitive, affective, and functional perspectives, strengthening the methodological coherence of the study.

III. Analysis of the Results

The analysis of the results was conducted across three complementary dimensions: (A) conceptual learning outcomes, (B) student engagement, and (C) perceived impact and usability of the TABDIM methodology supported by artificial intelligence tools. This multi-level approach enabled a comprehensive evaluation of the pedagogical intervention by coherently integrating cognitive, affective, and functional perspectives of the learning process.

A. Analysis of Conceptual Learning Outcomes

Conceptual learning was evaluated using a knowledge questionnaire consisting of 15 items, designed to assess students' understanding of fundamental concepts related to vitamins, including physicochemical properties, biochemical functions, structural characteristics, and nutritional relevance. The instrument was administered before and after the implementation of the GSL–TABDIM intervention.

A paired-samples t-test was applied to compare pre- and post-intervention scores for the $n = 22$ participants, allowing for the analysis of changes in individual performance over time. The results indicate a substantial increase in mean scores, from 65.68 prior to the intervention to 78.18 after its completion, reflecting a notable improvement in students' conceptual understanding (Fig. 1).

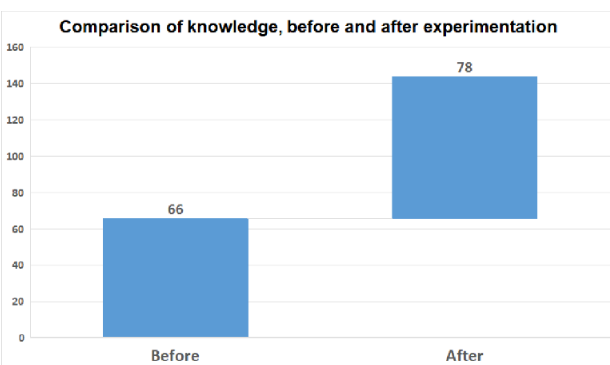

Fig. 1. Comparison of results before and after experimentation.

The observed variances (399.032 pre-intervention and 436.277 post-intervention) suggest a slightly higher dispersion after the intervention, which may be interpreted as a differential effect of the pedagogical strategy across students with varying levels of prior knowledge. This behavior is consistent with active and experiential learning environments, where learners progress at different rates depending on engagement, collaboration, and self-regulation.

The Pearson correlation coefficient ($r= 0.8006$) indicates a strong positive relationship between pre- and post-test scores, suggesting that students who entered the course with stronger initial knowledge also benefited substantially from the intervention, while those with lower initial scores exhibited meaningful gains. The resulting t statistic ($t = -4.3233$, $df = 19$) and corresponding p-values ($p < 0.001$ for both one- and two-tailed tests) confirm that the observed difference in means is statistically significant.

From an educational perspective, these results suggest that the integration of structured collaborative research, progressive cognitive scaffolding through TABDIM, and regulated AI support is associated with measurable improvements in conceptual learning. Importantly, the questionnaire items assessed not only factual recall but also conceptual relationships (e.g., enzymatic cofactors, signaling pathways, structural dimensions), indicating that learning gains extended beyond surface-level memorization.

B. Analysis of Student Engagement

Student engagement was analyzed using a 14-item commitment questionnaire (Table II), administered at the end of the intervention to capture students' perceptions regarding motivation, attention, effort, metacognitive reflection, and participation. The results are summarized numerically in Table II and visually represented in the radial plot shown in Fig. 2, which illustrates a consistently high level of engagement across most dimensions.

TABLE II. Questions from the commitment questionnaire and their results with n=22.

#	**Main question:** "Incorporating experimentation into my class was helpful…"	**Result**
1	Because the content and activities in class are interesting and enjoyable.	82
2	Because I felt excited when we started a new topic in class.	77
3	It allowed me to be very interested in studying new topics, because it's enjoyable for me.	82
4	It allowed me to listen carefully to the teacher's explanations.	77
5	It really allowed me to put in effort into class and on homework.	86
6	It allowed me to concentrate much better when the teacher introduced new topics or assignments.	77
7	It encouraged me to use different strategies to understand what the teacher was teaching and to complete the activities.	95
8	It helped me participate in class debates and discussions to complete the assignments.	77
9	It encouraged me to reflect on what I'd learned and gain a new understanding of what I knew when completing assignments.	95

10	It encouraged me to try to distinguish the most important information when I read for homework instead of just reading the text.	86
11	It helped me always try to ask myself questions when learning assignments because they help me understand key aspects of the topic.	82
12	It encouraged me to think of several ways to solve a task and then choose the best option.	82
13	It encouraged me to think about what I need to learn before starting work.	73
14	It encouraged me to ask myself how well I'm doing while learning something new.	91

The data reveal that a large proportion of students perceived the learning activities as interesting and enjoyable (82%) and reported feeling excited when new topics were introduced (77%). These findings suggest that the incorporation of experimentation, collaborative inquiry, and international interaction contributed to an emotionally positive learning environment.

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Fig. 2. Radial plot of the engagement questionnaire results.

In terms of motivation and effort, high percentages were observed for items related to sustained interest in studying new topics (82%), attentive listening during instruction (77%), and willingness to invest effort both in class and on homework (86%). These results indicate that the intervention supported not only situational engagement but also task-oriented persistence.

Notably, the highest values correspond to cognitive and metacognitive engagement indicators. For example, 95% of students reported using different strategies to understand the content and complete activities, and 95% indicated that the experience encouraged reflection on what they had learned, leading to a deeper understanding of the subject matter. These outcomes are particularly relevant in the context of engineering and science education, where strategic learning and self-regulation are critical for long-term academic success.

Additionally, students reported increased participation in class discussions (77%) and a stronger tendency to identify relevant information when studying independently (86%). Indicators related to self-questioning (82%), problem-solving strategy selection (82%), and self-assessment during learning (91%) further suggest that the pedagogical design fostered reflective and autonomous learning behaviors.

Overall, the engagement results indicate that the GSL–TABDIM strategy promoted a high level of affective and cognitive involvement, consistent with theoretical models of active and experiential learning.

C. Analysis of Impact and Usability of TABDIM

The perceived impact and usability of the intervention were evaluated using a 15-item questionnaire focused on students' experiences with AI-supported research activities and collaborative learning (Table III). The corresponding radial plot is presented in Fig. 3, illustrating uniformly high ratings across most dimensions.

The results show that 100% of participants reported satisfaction from learning new things, and 95% indicated discovering information they did not previously know, highlighting the exploratory and knowledge-expanding nature of the intervention. Similarly, a large majority reported that the experience helped them continue learning topics of interest (95%) and deepen their understanding of those topics (91%).

Indicators related to curiosity and immersion also received high scores, with 86% of students reporting full immersion when reading interesting topics, and 86% indicating increased curiosity regarding course explanations. These findings suggest that the integration of research-oriented tasks and AI-based support contributed to sustained attention and intellectual engagement.

From a motivational standpoint, the results are particularly noteworthy. All students (100%) reported increased persistence when studying and understanding course topics, and 91% felt encouraged to achieve their academic goals and complete assigned tasks on time. Additionally, high scores were observed for collaborative work (91%) and willingness to ask questions (86%), reflecting a positive classroom climate and effective social interaction.

Finally, affective indicators such as feeling happy in class (86%) and increased motivation to complete homework (86%) suggest that the intervention had a favorable impact on students' emotional experience, which is known to influence learning outcomes and retention.

Taken together, these results indicate that TABDIM, when integrated within a structured GSL framework and supported by regulated AI tools, was perceived as highly useful, motivating, and pedagogically meaningful by the participating students.

D. Synthesis of Results

Across the three dimensions analyzed—conceptual learning, engagement, and perceived impact—the results consistently suggest that the implemented strategy supported meaningful learning, active participation, and positive student experiences. While the study is limited by its pilot nature and sample size, the convergence of quantitative improvements in knowledge with strong engagement and usability perceptions provides coherent evidence supporting the educational value of the proposed approach.

D) Impact of the ANECAIQuim Chatbot

The impact of the ANECAIQuim chatbot was analyzed as a specific component of the implemented pedagogical architecture, with the aim of evaluating its contribution to the learning process, student engagement, and the perceived usefulness of the instructional strategy. Unlike approaches that examine conversational agents as isolated tools, in this study ANECAIQuim was integrated in a regulated and contextualized manner within the TABDIM methodology, functioning as a cognitive scaffolding mechanism during the research, synthesis, and reflection phases.

The results obtained from the impact and usability questionnaires (Table III and Fig. 3) indicate that students perceived the chatbot as a highly valuable resource for supporting their learning. In particular, 100% of participants reported that the use of the chatbot contributed to their satisfaction in learning new content, while 95% indicated discovering information previously unknown to them, suggesting that ANECAIQuim facilitated processes of conceptual exploration and disciplinary knowledge expansion.

Furthermore, a high proportion of students reported that the chatbot enabled them to deepen topics of personal interest (91%) and to sustain learning beyond mandatory course activities (95%), pointing to a positive impact on intrinsic motivation and self-regulated learning.

TABLE III. RESULTS FOR THE USEFULNESS ANALYSIS BASED ON THE QUESTION: “INCORPORATING EXPERIMENTATION INTO MY CLASS HELPED ME.”

#	***Main question: “Incorporating AI and research activities into my class was helpful:”***	**Result**
1	Because it gave me the satisfaction of learning new things.	100
2	Because it allowed me to discover new things I didn't know before.	95
3	Because it helped me study and continue learning the things that interest me.	95
4	It allowed me to learn more about the subjects that interest me.	91
5	It allowed me to fully immerse myself when reading interesting topics.	86
6	It sparked my curiosity about what the teacher explains.	86
7	It fostered my curiosity to read textbooks and/or scientific articles related to the class topics.	77
8	It helped me achieve my goals in class.	91
9	It encouraged me not to give up so easily when studying and understanding the class topics.	100
10	It encouraged me to attend class regularly and to always do my best to attend and be on time.	82
11	It encouraged me to finish the assigned course activities on time.	91
12	It helped me with collaborative work.	91
13	It encouraged me to ask the teacher questions.	86
14	It helped me feel happy in class.	86
15	It makes me want to do my homework.	86

These results are consistent with the role of the chatbot as a support tool for targeted consultation, conceptual clarification, and information organization during the development of research tasks. From a cognitive and metacognitive perspective, the data show that 86% of students reported greater immersion when reading and analyzing course-related content, as well as increased curiosity to better understand the instructor’s explanations and to explore scientific texts and articles associated with the topics addressed. This finding is particularly relevant, as it suggests that the use of ANECAIQuim did not replace instructor–student interaction but rather acted as a complementary resource that stimulated autonomous inquiry and reflective thinking.

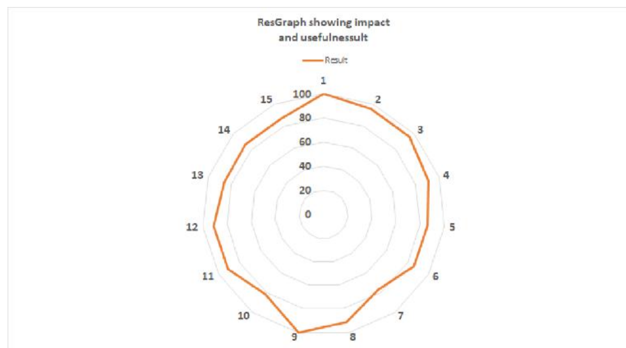

Fig. 3. Radial plot of the IMPACT AND USABILITY questionnaire results.

In terms of academic persistence and effort, the results indicate that 100% of students reported a greater willingness not to give up when facing content-related difficulties, while 91% indicated feeling more motivated to achieve their academic goals and complete assigned activities in a timely manner. These indicators suggest that the chatbot contributed to reducing initial cognitive barriers and to sustaining engagement throughout the collaborative research process.

Finally, results related to social interaction and classroom well-being show that the use of ANECAIQuim was associated with an increased willingness to ask questions to the instructor (86%), engage in collaborative work (91%), and experience positive emotions during the learning process, such as feeling comfortable and satisfied in class (86%). Taken together, these results reinforce the idea that the chatbot functioned as a facilitating pedagogical resource, integrated within an active and collaborative learning environment.

In summary, the findings suggest that the ANECAIQuim chatbot, when intentionally and systematically incorporated within a structured methodology such as TABDIM, can play a meaningful role as a cognitive and motivational support tool. Nevertheless, given the pilot nature of the study and the limited sample size, these results should be interpreted as exploratory evidence, opening avenues for future research with more robust experimental designs and larger samples.

The findings of this study are consistent with prior research highlighting the educational value of internationally collaborative and technology-enhanced learning environments. Previous studies on Global Shared Learning and international virtual collaboration have reported positive effects on student engagement, intercultural competence, and knowledge transfer when collaboration is intentionally embedded into curricular activities (Eguiluz et al., 2024; Membrillo-Hernández et al., 2023). Similarly, research on active and experiential learning in STEM education has shown that structured inquiry-based tasks and authentic assessment strategies contribute to deeper conceptual understanding and sustained student motivation (Prince, 2004; Kolb, 2015). In the context of artificial intelligence in education, recent systematic reviews indicate that conversational agents can effectively support learning processes when used as cognitive scaffolding rather than as standalone instructional tools (Holmes et al., 2022; Jiménez-García et al., 2025). The results obtained in this study align with these findings, suggesting that the pedagogical effectiveness observed is not attributable to the technology itself, but to its integration within a coherent instructional design that combines global collaboration, experiential learning, and regulated AI-based support.

IV. CONCLUSION

This study, conducted as a pilot experience with a limited sample of students, made it possible to analyze the impact of a Global Shared Learning strategy supported by the TABDIM methodology and the regulated use of artificial intelligence tools within an authentic higher education context. Even considering the limitations inherent to the sample size and the absence of a control group, the results provide consistent empirical evidence regarding the pedagogical potential of this approach to strengthen conceptual learning in science courses for engineering education.

The comparative analysis of pre- and post-intervention results revealed a significant improvement in students' academic performance, accompanied by a strong correlation between pre- and post-test scores. This pattern suggests that the combination of guided research, structured international collaboration, and progressive cognitive scaffolding supports not only knowledge acquisition but also the consolidation of deeper conceptual relationships, particularly in interdisciplinary content such as that addressed in this study.

Beyond cognitive outcomes, findings related to student engagement indicate that the incorporation of experimental, collaborative, and technology-mediated activities contributes to the creation of learning environments that are more participatory, motivating, and reflective. Students reported high levels of interest, sustained effort, self-regulation, and willingness to actively participate in academic discussions, reinforcing the relevance of intentionally designing educational experiences that integrate cognitive, affective, and social dimensions of learning.

Likewise, the integration of artificial intelligence using the specialized ANECAIQuim chatbot was perceived as a meaningful support resource during the research and synthesis processes, without displacing the instructor's role or students' critical thinking. The results suggest that, when such tools are incorporated in a regulated manner within a clearly defined pedagogical architecture, they can enhance curiosity, academic persistence, and efficiency in achieving learning goals, contributing to a more autonomous and meaningful learning experience.

Overall, this work provides preliminary evidence supporting the value of integrating international collaboration, experiential learning, and advanced digital technologies in higher education, particularly in introductory science and engineering courses. Although future studies with more robust experimental designs and larger samples are required to generalize the findings, the results presented here constitute a solid foundation for further exploration of hybrid and internationally oriented educational models capable of effectively responding to the educational demands of the twenty-first century.

ACKNOWLEDGMENT

The authors express their sincere gratitude for the financial and technical support provided by Writing Lab, Institute for the Future of Education at Tecnologico de Monterrey, Mexico, in the creation of this workpreferred spelling of the word.

ANNEXES

Tools Used for the Evaluation of the Control and Experimental Groups:

a) Questionnaire 1: Knowledge
https://forms.office.com/r/dfAhp4YyuP

b) Questionnaire 2: Engagement
https://forms.office.com/r/xR3F96GdL9

c) Questionnaire 3: Impact and Usefulness
https://forms.office.com/r/U0wBPwbTRw

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